REMARKS

The Applicants thank the Examiner for the thorough consideration given the present application. Claims 1-14 are pending. Claims 1-14 are amended. Claims 1 and 9 are independent. The Examiner is respectfully requested to reconsider the rejections in view of the amendments and remarks set forth herein.

Claim for Priority

It is gratefully acknowledged that the Examiner has recognized the Applicants' claim for foreign priority. In view of the fact that the Applicants' claim for foreign priority has been perfected, no additional action is required from the Applicants at this time.

Drawings

The Applicants have not received a Notice of Draftsperson's Patent Drawing Review Form PTO-948, indicating whether the formal drawings have been approved by the Official Draftsperson. Clarification in the next official communication is respectfully requested.

Acknowledgement of Information Disclosure Statement

The Examiner has acknowledged the Information Disclosure Statements filed on December 17, 2001 and March 18, 2002. Initialed copies of the Forms PTO-1449 have been returned by the Examiner. No further action is necessary at this time.

Specification Objection

The Examiner has objected to the specification because of several informalities. In order to overcome this objection, Applicants have provided a substitute specification and marked-up copy of the specification in order to correct the deficiencies pointed out by the Examiner. No new matter has been added. Reconsideration and withdrawal of this objection are respectfully requested.

Rejection Under 35 U.S.C. §112, second paragraph

Claims 1-14 stand rejected under 35 U.S.C. § 112, second paragraph as being indefinite. This rejection is respectfully traversed.

In order to overcome this rejection, Applicants have amended claims 1 and 9 to correct each of the deficiencies specifically pointed out by the Examiner. In addition, claims 2-8 and 10-14 have been amended merely to place them in a form more typical of U.S. practice.

Applicants respectfully submit that the claims, as amended, particularly point out and distinctly claim the subject matter which Applicants regard as the invention.

Accordingly, reconsideration and withdrawal of this rejection are respectfully requested.

Therefore, independent claims 1 and 9 the claims depending therefrom are in condition for allowance. Accordingly, reconsideration and withdrawal of the rejection under 35 U.S.C. §112, second paragraph are respectfully requested.

CONCLUSION

All of the stated grounds of rejection have been properly traversed, accommodated, or rendered moot. It is believed that a full and complete response has been made to the outstanding Office Action, and that the present application is in condition for allowance.

If the Examiner believes, for any reason, that personal communication will expedite prosecution of this application, he is invited to telephone Carl T. Thomsen (Reg. No. 50,786) at (703) 205-8000.

Pursuant to 37 C.F.R. §§ 1.17 and 1.136(a), Applicant(s) respectfully petition(s) for a one (1) month extension of time for filing a reply in connection with the present application, and the required fee of \$110.00 is attached hereto.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§1.16 or 1.17, particularly extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

James M. Slatte

Reg. No. 28,380

0365-0525P Attachment

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METHOD AND APPARATUS FOR MEASURING WATER CONTENT

CROSS-REFERENCE TO RELATED APPLICATION

This application is the national phase under 35 U.S.C. § 371 of PCT

International Application No. PCT/FI00/00542 which has an International filing date

of June 15, 2000, which designated the United States of TAmerica

and was published in English.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a method according to the preamble of claim 1 for measuring the water content of a liquid.

Description of Background Art

[0003] The invention also relates to an apparatus for measuring the water content of a liquid.

US Pat. No. 5,642,098 discloses a ring oscillator circuit, wherein electrical properties of the oil are measured with a number of measurement heads which measure the same parameter.

electrodes (finger electrodes are coated with a conducting polymer. Water contained in

the oil hydrates the polymer and thus modifies its conductivity. Also detects possible

acids by way of protonation.

US Pat. No. 5,331,287 describes a sensor, wherein interdigitated

US Pat. No. 5,644,239 measures the electrical conductivity of a liquid
(oil) at two elevated temperatures. The technique may be complemented with a
possible optical measurement of oil opacity. A "figure of quality" may then be
computed for the oil from these parameters.
[0007] US Pat. No. 5,656,767 describes a sensor system for measuring the
change of an electrical parameter value (e.g., capacitance) in oil as a function of time.
The same oil at a clean (dry) state may be used as a reference value. The same
technique may be varied in multiple ways, e.g., by heating the oil sample.
[0008] Conventional techniques are handicapped in many aspects. Common
methods for sensing absolute water volume content over the entire range of 0-100 $\%$
are the measurement of the dielectric coefficient and measurement of IR absorption.
Both of these methods have in common that they require a zeroing step of the
measurement system, whereby the reading must be reset to zero water content when
the sensor is brought to measure an entirely dry (water-free) liquid. This step can be
accomplished as a discrete zeroing operation or by using a sample of entirely dry oil in
the sensor as a reference.
[0009] An additional complication arises therefrom that such a zero setting is
typically dependent on the temperature.
Also other factors besides the water content may affect the zero-value
with the aging of the liquid.
[0011] Methods measuring the absolute water content are favored at high water
contents (in the order of several per cent).
At lower water contents, problems generally arise from the marginal
detection threshold and offset uncertainty (error of zero setting).

A relative value (aw) measurement method gives information on the water content value in relation to that of a fully saturated situation. However, a conversion to the volume percentage value of absolute water content remains undefined unless a conversion factor for the liquid being measured is known. The aw measurement method is suitable for use at low water content levels (nonsaturated and not emulsified), whereby the measurement has a sufficiently high sensitivity. Moreover, the method is free from zeroing problems.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the drawbacks of the above described techniques and to provide an entirely novel type of method and apparatus for measuring the water content of a liquid.

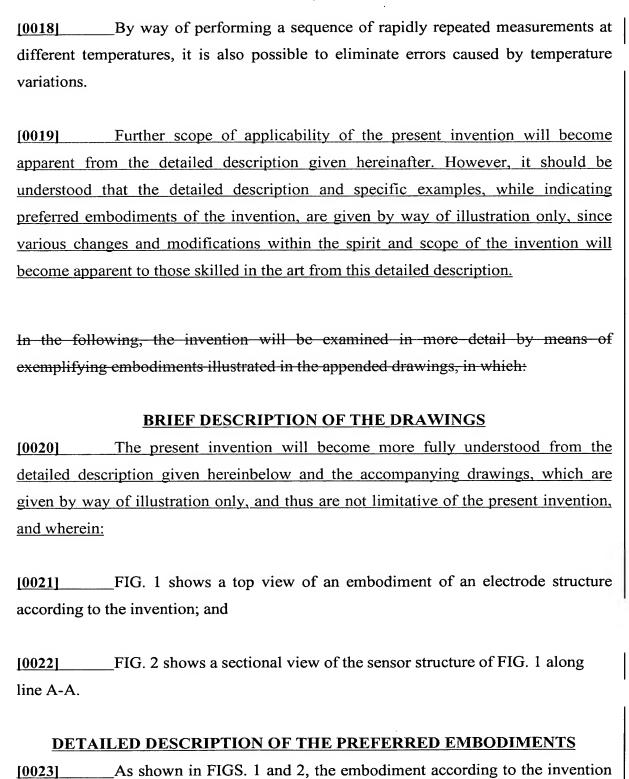
The goal of the invention is achieved by way of measuring the water content of the oil/liquid using two different methods simultaneously, whereby the measurement technique is based on an absolute value measurement method complemented with a relative value measurement method.

More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the apparatus according to the method is characterized by what is stated in the characterizing part of claim 9.

[0016] The method and apparatus of the present invention offers offer significant benefits.

The combination of an absolute value measurement method with a relative value measurement method (aw-type of measurement) makes it possible to eliminate the need for a zeroing step in the absolute value measurement.



can be implemented using a structure, wherein onto the surface of a substrate 4 is

formed a combination of three electrodes. The surface of the substrate 4 has directly

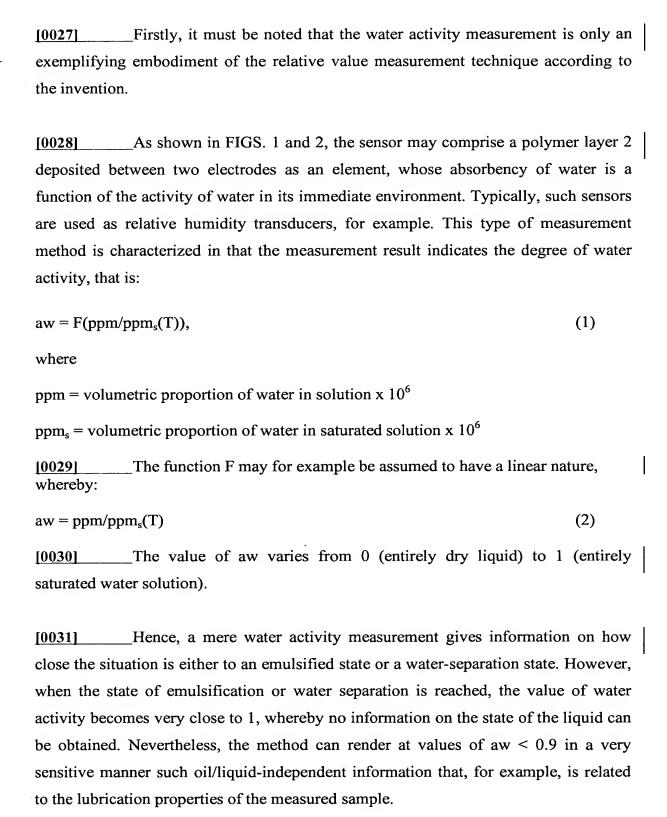
deposited thereon a pair 3 of bottom electrodes formed by electrodes 5 and 6. In the illustrated case, the electrodes are shaped into finger electrodes, more specifically disposed as so interdigitated electrodes, whereby the interelectrode surface is maximized by using an electrode structure having the finger electrodes displaced between each other. The length of the adjacent edges of the interdigitated electrodes 5 and 6 is equivalent to the area of superimposed electrodes in a planar capacitor. The width and interelectrode gap of the electrodes 5 and 6 typically are in the range of 5 to 500 micrometers. In addition to its interdigitated finger electrode portion, the electrode 6 has a planar area 7. Furthermore, the electrodes 5 and 6 include contact pad areas C 1 and C2 for connection of the electrodes to measurement means. Onto the bottom electrode pair 3 is deposited a polymer layer 2 having a thickness of 0.5-5 micrometer typical. The area of the polymer layer 2 may also be extended over the interdigitated finger electrode structure 5 and 6, whereby it also functions as a passivation layer and reduces the effect of conducting particles contained in the liquid sample on the measurement result. Onto the polymer layer 2 is deposited a water-permeable top electrode 1 with a contact pad area C3 for external connections. The top electrode 1 is aligned above the rectangular solid area 7 of the electrode 6 in order to form a planar capacitor structure.

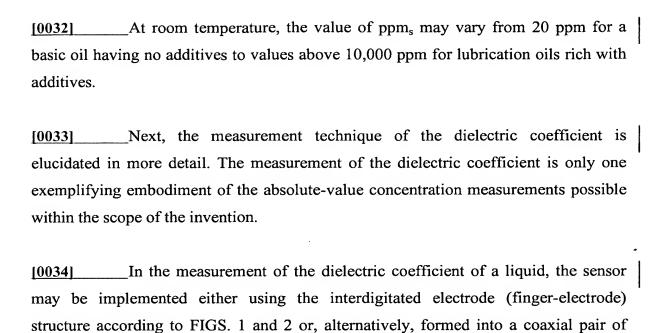
The structure illustrated in FIGS. 1 and 2 is utilized as follows. The dielectric coefficient of the liquid under measurement is measured over the contacts C1 and C2 of the electrodes 5 and 6. Respectively, the relative value measurement is performed over the electrodes 6 and 1, that is from the contacts C1 and C3.

[0025] Advantageously, the liquid whose water content is measured is oil, but the water content measurement according to the invention may also be performed on other liquids such as a hydraulic fluid, gasoline or a coolant as well.

[0026] According to the invention, the measurement of the activity of water can

be carried out as follows.





electrodes brought into contact with the liquid to be measured. The output signal of the

sensor is dependent on both the dielectric coefficient and water content of the liquid

$$\varepsilon_{\rm r} = \varepsilon_0 + {\rm F(ppm)} \tag{3}$$

where

under measurement:

 ε_0 = dielectric coefficient of entirely dry liquid,

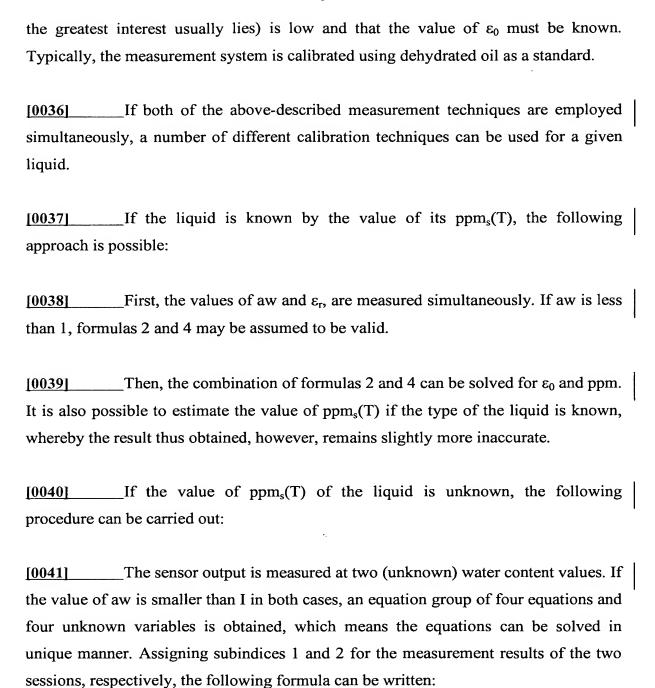
F(ppm) = a function dependent on the water content. Over a limited range of water content, the function may be assumed to be linear, that is:

$$\varepsilon_{\rm r} = \varepsilon_0 + {\rm a} \times {\rm ppm} \tag{4}$$

where

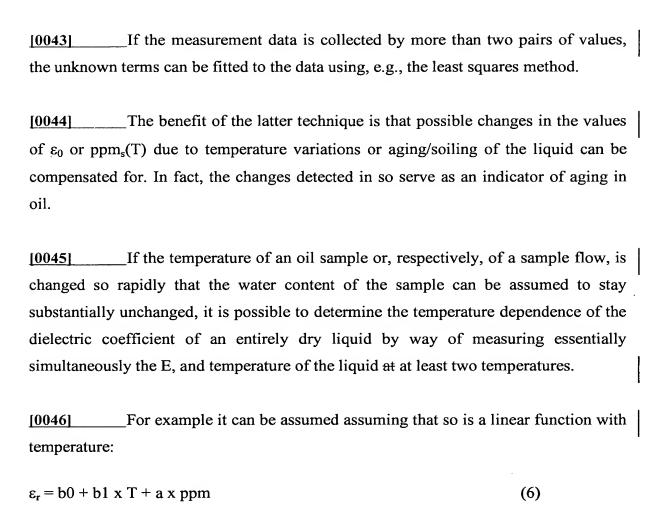
a = constant independent of the liquid type.

An advantage of the dielectric coefficient measurement technique is that it covers the entire possible measurement range from 0 to 100 vol-% water. A disadvantage of the method is that its sensitivity at the low end of water content (where



$$\varepsilon_0 = (aw_2 \times \varepsilon_{r1} - aw_1 \times \varepsilon_{r2})/(aw_2 - aw_1)$$
 (5)

This procedure may also be arranged to take place automatically during the continuous function of the measurement apparatus if the water content of the liquid under measurement varies.



whereby the following formula can be formed

$$\varepsilon_{r}(T2) - \varepsilon_{r}(T2) = b1 \times (T2 - T1)$$
 (7)

wherefrom the coefficient b 1 can be solved. Also in this case, it is possible to collect values at a greater number of temperatures and then fit the measurement results with a the help of the least squares method. This technique gives a continuously reliable parameter estimate value for so as the temperature varies.

Also the temperature dependence of ppm_s(T) can be determined simultaneously.

Over a limited temperature range, a general assumption may be made as:

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According to a preferred embodiment of the invention, the zeroing operation is performed automatically each time the measurement of aw gives a sufficiently low value. The lower the value of aw the more accurate the zeroing operation. The uncertainty of the method is associated with the value of ppm_s(T) that is dependent on the type of liquid under measurement and thus can be obtained by an "intelligent guess".

Advantageously, these two determinations may be carried out

simultaneously.

According to another preferred embodiment of the invention, two samples of the liquid/oil having different water contents are taken. Then, the measurement system may intentionally be set to measure two samples of different water contents or, alternatively, gradual accumulation of data from the measured process is utilized, whereby the natural variation of water content in the monitored process is availed of. This approach also gives a value for ppm_s(T) on the basis of which it is possible according to the invention to compute from the measured value of aw the correct value of ppm without resorting to an "intelligent guess".

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Attorney Docket No.: 0365-0525P
Marked-Up Copy of Substitute Specification

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[0052] If a continuous data collection from the monitored process is performed
using simultaneously a sliding-window technique for "dumping" obsolete data, it is
also possible to compensate for changes in both the value of ppms and ϵ_0 due to aging
of the liquid/oil.
[0053]In the case that the process also is subjected to temperature changes, the
temperature dependencies of ppm $_{\rm s}$ and ϵ_0 can also be resolved.
The invention being thus described, it will be obvious that the same may
be varied in many ways. Such variations are not to be regarded as a departure from the
spirit and scope of the invention, and all such modifications as would be obvious to
one skilled in the art are intended to be included within the scope of the following
claims.